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Assessing relationship between vulnerability and capacity: An empirical study on rural flooding in Pakistan

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ABSTRACT

Vulnerability and capacity assessment of hazard-prone communities is integral to the development of efficient disaster risk reduction strategies. Both concepts are known to be inter-linked and inter-dependent in disaster risk science as well as climate change adaptation literature. However, a holistic relationship between these two concepts is rarely studied which this research aims to assess by conducting an empirical study in Pakistan in the context of rural flooding. A total of 120 samples are collected using household survey from four rural communities in two different districts. Indicators are chosen through rigorous literature review and categorized into human, social, economic, physical and natural assets. A total of 24 and 19 indicators for vulnerability and capacity respectively are used to develop the resultant index. Results show that the two analyzed districts have a similar pattern of vulnerabilities; however, in both districts, capacities differ with respect to different livelihood categories. A significant negative correlation is observed in the study area which confirms the relationship theorized in literature between vulnerability and capacity. The methodology adopted in this study can also be replicated to pragmatically validate the relationship between both of these concepts for future extreme climatic events and disasters.

1. Introduction

Vulnerability is a multifaceted phenomenon in disaster risk reduction and climate change adaptation, with different contexts, dimensions, and scales [20,87]. In simple terms, it is the propensity or predisposition of a system to be adversely affected by an external hazard [46]. On the other hand, capacity is understood to be a concept opposite to vulnerability. It refers to forces that influence the ability of a system to adapt to and reduce the effects of an external stimulant [30,90]. In recent decades, a strong emphasis has been given to understand vulnerabilities and capacities worldwide to prepare communities for climate change and sustainable development [47]. The relationship between vulnerability and capacity is of great importance in the development of disaster risk reduction strategies for hazard-prone communities [35]. While it is imperative to assess vulnerability and capacity individually, their interrelationship must also be studied to develop an effective Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) discourse.

Sustainable Development Goals (SDGs) and Sendai Framework for Disaster Risk Reduction have highlighted the importance of identification, assessment, and reduction of vulnerability for disaster risk reduction [20]. Although climate change poses the same hazard on urban and rural areas, the latter is deemed more vulnerable [95]. While almost half of the world's population lives in rural areas, 90% of it is concentrated in Asia and Africa [96], where vulnerability and capacity assessment becomes crucial [36]. In the developing world, natural resources are singularly affected by climate change and natural hazards, rendering rural communities particularly vulnerable [33,63,64].

Pakistan is an agro-industrial developing country in South Asia with the population of 207.7 million. It has an average GDP growth rate of 5.5% and is ranked 147th on the Human Development Index [50,79,93]. High development disparity prevails between urban and rural areas of the country. Ref. [85] assert that rural areas farther away from primary cities are less developed, and their development disparity is much worse. Rural areas are very important to assess because they accommodate more than 65% of the country's population and are highly

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exposed and vulnerable to natural hazards and climate change [3]. The agriculture sector alone – vital to the livelihoods of both rural and urban communities – employs almost 43% of Pakistan's workforce and contributes 20% to national GDP [65].

Pakistan has been ranked 1st in the 2010 and 5th in the 2014 iterations of the climate risk index [61]. Flooding has become a regular phenomenon in Pakistan. It is estimated that between 1970 and 2016, flood events took 13 thousand lives, affected 80 million people and caused economic damages of US$ 21 billion [38]. Due to a changing climate, floods have become more frequent and intense, posing serious challenges for flood disaster management in Pakistan [72]. These floods have largely affected the poor rural population, caused massive population displacement, took thousands of lives and damaged millions of hectares of cropped area [70]. Most of the urban areas and industrial hubs, however, have remained safe [10]. It has, therefore, become vital to assess vulnerability and capacity in flood-prone rural communities in order to develop effective flood risk reduction measures.

2. Theoretical background

2.1. Vulnerability

Conceptually, vulnerability is considered as having both negative and positive elements [15]. In the context of climate change adaptation, vulnerability is defined as the degree to which a system is susceptible to the adverse effects of an environmental hazard [47]; whereas, in disaster risk reduction, it can be understood in terms of the characteristics and circumstances of a system that make it susceptible to the damaging effects of an external hazard [97]. Vulnerability of a system can be distributed into its component core factors such as exposure of a system to hazardous conditions, susceptibility of a system to be affected, and the capacity of the system to recover from these conditions [90]. It is important to note that the term sensitivity is used in climate change research whereas the terms susceptibility and fragility are prevalent in disaster risk reduction literature [17]. Ref. [15] consider exposure and susceptibility as the negative sides of vulnerability, and capacity as its positive side. The study phrases the negative side as "revealed vulnerability", which is composed of exposed and susceptible elements of a system which have experienced losses and damages.

In addition to core components, vulnerability can also be framed in terms of five thematic dimensions. The sustainable livelihoods framework views vulnerability in terms of capitals or assets possessed by people in a community for procurement of their livelihoods which can be subcategorized as human, social, financial, physical and natural assets [37]. Human assets are the skills, knowledge, health and physical capabilities possessed by a community's working labor force instrumental in implementing livelihood procurement strategies. Social assets refer to social networks, affiliations, and associations that people subscribe to for livelihood fulfillment [37]. The economic assets of a community are its "capital base" which encompass insurance, credit and debt, and possession of cash and savings which are instrumental to successfully gain a livelihood. The natural and environmental assets are a community's natural resource stocks and environmental services [66]. Finally, physical assets refer to infrastructure, production equipment, and technologies utilized by communities for livelihood procurement which are vulnerable to external hazards [37].

2.2. Capacity

Capacity is one of core factors in the understanding of vulnerability of a system to external hazards. It is considered to have binary dimensions in terms of adaptive and coping capacities. Adaptive capacity refers to forces that influence the ability of a system to adapt to the external stimulant [90]. In other words, it is the ability of a system to adjust to potential or expected damage, to take advantage of opportunities, or to respond to consequences [46]. Any adaptation measure undertaken by a system is a manifestation of its adaptive capacity [90]. On the other hand, coping capacity, according to UNISDR, can be defined as a combination of all strengths and resources available within a system that can reduce the effects of an external hazard [97]. Whereas adaptive capacity might also refer to the capacity of a system to adapt to expected future hazards, coping capacity is often used to characterize the availability of resources to deal with an external hazard. Such a differentiation can bear importance in measuring and analyzing vulnerability [20]. Since capacity and vulnerability are interrelated, adaptive capacity is also seen as a function of human, social, financial, physical and natural assets of a community in the sustainable livelihoods framework [37], and is operationalized within this context in this paper.

2.3. Frameworks of vulnerability and capacity

Over the past decades, academic pursuits into systemization of views and concepts of vulnerability have resulted in the formulation of a number of theoretical frameworks, which are considered instrumental in the development of vulnerability measurement approaches. The sustainable livelihood framework frames vulnerability into shocks, trends, and seasonality, each of which can be influenced by altering interactions between institutional, social, cultural and economic structures and processes [37]. Bohle's double structure of vulnerability considers vulnerability in binary terms with internal (capacity) and external (hazard) components [23]. Turner views vulnerability in socio-ecological terms and dissects vulnerability into exposure and response, and adaptation as a means for increasing resilience [94]. The pressure and release model considers disaster risk as a product of natural hazard and vulnerability of a system [21,103].

Alternatively, integrative approaches view vulnerability and disaster risk from a holistic viewpoint. Ref. [29,31] first demonstrated that vulnerability can be characterized on the basis of geographic exposure and susceptibility to natural hazards, an ability to cope, and socio-economic conditions. The Bogardi and Birkmann [22] and Cardona [32] "BBC" framework holistically stresses that vulnerability analysis must be linked with sustainable development. It also frames vulnerability in a dynamic feedback loop system by simultaneously assessing exposure, susceptibility, coping capacities and potential intervention tools to reduce the vulnerability of a system [20]. BBC framework considers exposure and susceptibility – the so-called negative side – as "revealed vulnerability", whereas lack of capacities and intervention tools are considered as "emergent vulnerability" [15]. The IPCC SREX framework considers disaster risk as a function heavily determined by social conditions [45]. The MOVE framework focuses on process-oriented vulnerability by linking it with social processes, involving dynamic feedback loops. It also differentiates vulnerability into key factors (exposure, susceptibility, and capacity) and thematic dimensions (social, economic, institutional, cultural etc.). Furthermore, the framework stresses risk governance as integral to response and adaptation processes [16]. The integrated flood risk framework shows capacity component as inversely proportional to risk and countering vulnerability [86]. Owing to the fact that vulnerability is seen differently in different contexts and dimensions, this research considers vulnerability in terms of "revealed vulnerability", which encompasses its aforementioned negative side involving exposure and susceptibility [15].

The quantification of vulnerability is underdeveloped as compared to the mapping and measuring of hazards [18]. However, several studies have assessed vulnerability and capacities using different methods. Ref. [34] developed a social vulnerability index and used factor analysis to assess vulnerability to hazards at the county level in the United States of America, but that research did not incorporate capacity indicators. Ref .[26] assessed the relationship between exposure – flood damages, exposure – vulnerability and coping – vulnerability to flood hazards in Bangladesh. In Germany, researchers used vulnerability and capacity indicators for the assessment of social vulnerability and its validation of

an index to river floods [40]. Similarly [89], explored a multi-criteria to assess flood vulnerability by incorporating social, economic and ecological dimensions of risk and capacity. Ref. [24] used the household survey to develop a community-based disaster risk index to assess vulnerability and capacity at the district level in Indonesia. Ref. [13] compared parametric modeling (such as flood vulnerability index, where vulnerability is a component of exposure, susceptibility, and resilience) and physically-based modeling approach to assess flood vulnerability in Kenya. Ref. [101] developed world risk index and assessed national level risk and vulnerability (in terms of sensitivity, coping and adaptive capacity) of 173 countries to multiple hazards. Ref. [62] assessed social vulnerability and adaptive capacity in districts of Arunachal Pradesh, India, to climate change by developing an index. Ref. [76]; based the sustainable livelihood framework, assessed climate change vulnerability and capacity of Himalayan communities using climate vulnerability index (CVI) and current adaptive capacity index (CACI). Ref. [105] carried out a vulnerability and adaptation assessment of flood-affected coastal communities in Bangladesh. Ref. [92] created an index to assess the multifaceted phenomenon of socio-economic vulnerability in Italy where vulnerability was considered as susceptibility, coping capacity and adaptation measures.

Local studies assessing vulnerability and capacities are limited. Ref. [68] utilized informal interviews and household surveys to qualitatively assess the vulnerability of flood-affected rural communities. National Disaster Management Authority (NDMA) used limited indicators to assess vulnerability to multiple hazards at the district level [72]. Ref. [83] assessed multi-hazard risk and vulnerability at the district level by

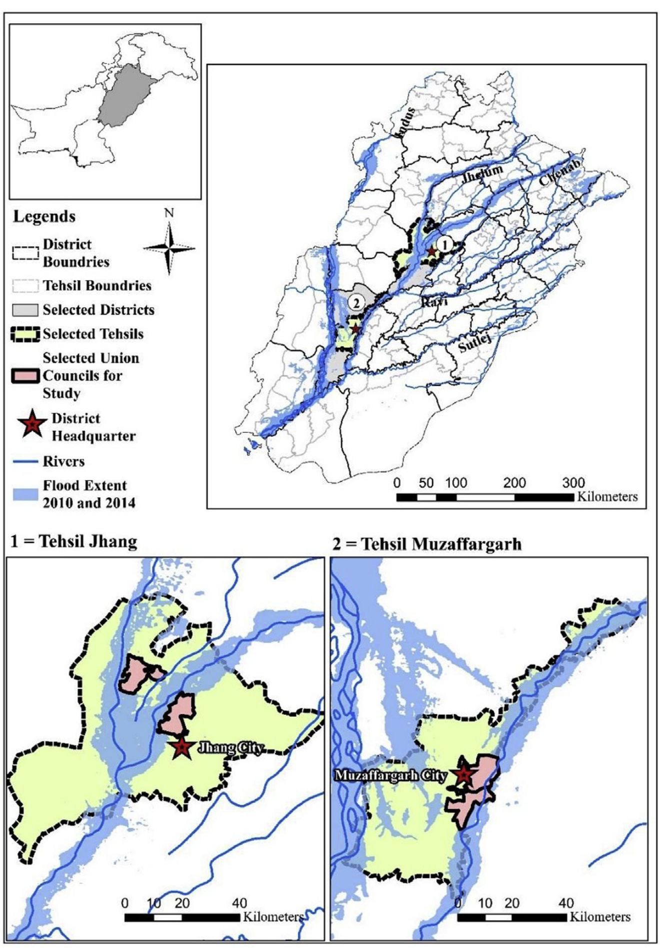

Fig. 1. Case study areas: 1) Tehsil Jhang and 2) Tehsil the Muzaffargarh and associated union councils. Data source: United Nations Office for the Coordination of Humanitarian Affairs UN-OCHA [98].

only using past data on physical, social, and economic indicators. Ref. [57] developed a human vulnerability index (HVI) to the flood hazard although it was invalid at the community level. Ref. [11] carried out the impact and vulnerability assessment of flood-affected communities of Punjab by adopting a livelihood approach and using descriptive statistics. A similar method was used to assess flood vulnerability at the local level in Khyber Pakhtunkhwa [58]. Ref. [3] assessed the vulnerability and capacity of rural communities of Punjab to climate change. Ref. [54] used a participatory approach and developed a weighted matrix index to assess the changes in vulnerability and capacity of flood-affected communities in Punjab. Ref. [86] measured risk, vulnerability and capacity to floods by developing a comprehensive index. Some of the studies mentioned here were limited to regional scale (for example [57,72,83], whereas others were conducted at local scale (for example [3,54,70,86]. None of these studies have explored the relationship between vulnerability and capacity.

Most of the aforementioned models and frameworks consider capacity as an integral part of the vulnerability and also predict a strong relationship between them. Many researchers have argued critically but little precedence for empirical studies is found in which empirical testing of the relationship between vulnerability and capacity is carried out (see Ref. [26]). The research that came closest to empirical testing was done by Ref. [14]; who used the index-based approach to assess social vulnerability and community resilience at the county level in the USA. They found a correlation between high vulnerability and low resilience. This study also uses an index-based approach to correlate vulnerability and capacity of flood-prone rural communities by streamlining their own distinct indicators.

3. Materials and methods

Under the umbrella of sustainable livelihood framework, five key dimensions based on livelihood assets – human, social, economic, physical and natural – [37] are taken to assess the vulnerability and capacity. Vulnerability and capacity indices are constructed through standardizing/transforming indicators into weights as used by some researchers [42,84,86,100]. Pearson's correlation is employed to ascertain the relationship between vulnerability and capacity.

3.1. Selection of study area and sampling

Punjab[1] is the most populated province of Pakistan (see Fig. 1). It is inhabited by 110 million people and is home to more than half of the country's entire population [79]. It is Pakistan's most fertile region, contributing 12.6 million hectares (57%) of the country's total cultivatable area, and plays a vital role in the national economy [27]. The rural area of Punjab is highly prone to flood hazard, and multiple flood events have occurred during the last 10 years. The flood events between 2010 and 2014 were particularly intense and of note, destroying physical infrastructure, displacing millions of people, affecting thousands of acres of crops and damaging countless villages.

For sampling, a multistage sampling technique was adopted. At first, 10 districts facing high flood risk were selected using the NDMA report [72]. Districts which were heavily affected in the past 7 years were shortlisted. Punjab Development Statistics (PDS) were then used to finalize the selection districts based on socio-economic characteristics (e.g. proportion of the rural population, household size, literacy rate, income, occupation) as well as the level of experienced losses and damages [27,80]. This process revealed Muzaffargarh and Jhang as the most appropriate study districts. Afterwards, with the consultation of officials of District Disaster Management Authority (DDMA) and local planning officials, flood-affected tehsils[2] and union councils (UCs) were

[1] A word of the local language meaning 'land of five rivers'.

[2] Tehsil is an administrative unit (sub-district) in local context.

decided. Severely affected UCs such as Pukkewala and Phabbarwala from sub-district Jhang and Talairi and Thatta Qureshi from sub-district Muzaffargarh were selected (see Fig. 1). Lastly, the selection of villages for the household survey was made randomly after consultation with municipality officials and local NGOs. These UCs and villages were confirmed by superimposing flood extent maps of 2010/2014 events with the location of settlements in GIS. A total of twelve villages were surveyed, and ten households were randomly selected from each village which resulted in a convenient sample of 120 households. The survey was carried out until the desired sample was collected.

3.2. Description of selected study areas

Jhang is located in central Punjab about 280 km from the provincial capital. It is an agro-industrial district with the total land area of 6,166 square kilometers. About 1.87 million (76%) of the population lives in rural settlements and a majority depends on agriculture for livelihood. The mean household size is 6.5, literacy rate of about 37% and approximately 45% population is below poverty line [27,53]. Two major rivers cross the district i.e. Chenab and Jhelum (see Fig. 1). The district also faces a high risk of riverine floods. Between 2010 and 2014, flood events displaced almost 0.25 million people, destroyed over 30,000 houses, affected 950 settlements and affected half a million hectare of cropped area [71,73,80]. Muzaffargarh is situated in southern Punjab, approximately 400 km from provincial capital Lahore. The district spreads over an area of 8,249 square kilometers with a population of 4 million. Its population is predominantly rural (approximately 86%, or about 3.5 million people) and engaged in farming. The average household size is 6.7, the literacy rate is 28%, and almost 58% of the population is living below the poverty line [27,51,53]. The district is surrounded by two major rivers – Indus in the north and Chenab in the south – both of which have caused yearly large-scale flooding between 2010 and 2014 (see Fig. 1). These flood disasters damaged over 225 thousand hectares of crop area, affected over 1,000 villages, displaced more than 1.8 million people and destroyed over 184 thousand houses [71,73,80].

3.3. Questionnaire design and data collection

A semi-structured questionnaire was prepared for the household survey. The questionnaire was prepared in English consisting of questions related to the indicators mentioned in Tables 1 and 2. The questionnaire was divided into five parts, i.e. human, social, financial, physical and natural. Each part consisted of ten to fifteen questions, and the complete questionnaire consisted of 75 questions. Close-ended and open-ended questions were included. A pretest with 10 questionnaires was also conducted to refine and streamline the questionnaire. Each questionnaire took an approximately half an hour. Due to cultural and language limitations in the study districts, local field assistants were hired and trained to collect the data. The final survey was conducted under the supervision of the lead author. Female participation was ensured in the survey.

3.4. Indicators selection and index development

Indicators were selected using an extensive review of the literature (see Tables 1 and 2), and data on each indicator was collected through the household survey. Twenty-five indicators were chosen for the vulnerability component and 19 indicators were selected for the capacity component. In order to develop the index, a methodology based on previous studies (see Refs. [1,84,87]) was adopted. Each indicator was further divided into classes, taking into account the characteristics and nature of that indicator. Considering this, different types of classification were done i.e., with two, three, four and five classes as required in each case. These classes represent the degree of variation possible in each indicator. Moreover, it also helps in identifying the differences between case study areas, without assigning separate weights based on the area characteristics. For each class, weights were assigned depending on the type of response class for each indicator. The highest vulnerability and capacity classes were assigned weight value of 1 whereas the lowest as 0. The indicators with dichotomous responses were given the weights of 1 and 0. The indicators with three classes were given weights between 1, 0.5 and 0, with four classes 1, 0.66, 0.33, 0 and five classes 1, 0.75, 0.5, 0.25, 0 and with six classes 1, 0.8, 0.6, 0.4, 0.2, 0 (see Table 1 for weights detail). Considering their respective weights, original datasets were standardized for computation of composite index using Equation (1). Equations (2) and (3) were used to develop vulnerability and capacity index respectively. Tables 1 and 2 show the indicators along with classes, weights, explanation and empirical studies for constructing vulnerability and capacity index.

$$CI = \frac{(W_1 + W_2 + W_3 + \ldots W_n)}{n} = \sum_{i=1}^{n} \frac{W_i}{n} \tag{1}$$

Where,

CI is the composite index,

W_1 to W_n are respective weights assigned to indicators, and n is the number of indicators used for computing the composite index.

Following this general principle, the Vulnerability Index (VULI) and Capacity Index (CAPI), are calculated (see Equations (2) and (3)).

$$\text{Vulnerability Index (VULI)} = \sum_{i=1}^{25} \frac{VW_i}{n} \tag{2}$$

$$\text{Capacity Index (CAPI)} = \sum_{i=1}^{19} \frac{CW_i}{n} \tag{3}$$

4. Results and discussion

4.1. Socioeconomic profile of respondents

Both selected sub-districts were affected by the flood events between 2010 and 2014. Characteristics of flood events in Jhang and Muzaffargarh are quite similar in terms of the type of flooding, flood management issues, and poor response measures. However, the household survey revealed that socioeconomic characteristics of households differ (see Table 3). Compared to sub-district Jhang, the literacy rate in Muzaffargarh is quite low. Household size is slightly higher in Muzaffargarh than in Jhang. Average household size in both sub-districts is almost 10. The predominant occupation of the household was agriculture specifically in Muzaffargarh, whereas in Jhang, urban-based economic activities like off-farm labor and government jobs were present. Income level in Muzaffargarh was slightly higher than in Jhang, mainly due to multiple earning members in a household. Moreover, the majority of households owned agriculture assets like land indicating the secondary source of income. Overall, the differences in the mentioned characteristics are also due to the level of urbanization in both sub-districts. Muzaffargarh seems more deprived in terms of socio-economic characteristics as compared to Jhang, which is also identified by Jamal in his study “Multiple deprivations for Pakistan” where Muzaffargarh ranked 34 and Jhang 29 out 36 districts in Punjab [52].

4.2. Vulnerability assessment

Vulnerability assessment was done for various livelihood assets of flood victims. When comparing both sub-districts, they present more or less the same pictures of vulnerability. However, it is evident that Muzaffargarh is slightly more vulnerable (scores 0.56) compared to sub-district Jhang (0.52) particularly in terms of physical assets, but less vulnerable when it comes to natural assets (see Table 4 and Fig. 2a).

In the human dimension, the higher vulnerability of Muzaffargarh

Table 1
Vulnerability indicator, associated weights, explanation, and references.

Sr. #	Indicators	Classes	Weights	Explanation	References
Human					
1	Households with children under the age of 15 years	> 6 4 to 6 1 to 3 0	1 0.66 0.33 0	Households with a higher number of children under the age of 15 are more vulnerable	[77,82,92]
2	Households with elderly more than 60 years old	> 3 1 to 3 0	1 0.5 0	Households with a higher number of elderly are more vulnerable	[77,89,92]
3	Presence of handicapped/special people or persons with serious illness	0 1 2 > 2	0 0.33 0.66 1	Handicapped people or persons with serious illness need special assistance and hinder mobility in case of emergency and therefore are more vulnerable to a hazard	[5,12,43,77,92]
4	Number of school dropouts/could not attend school from a household after the flood	0 1 to 2 3 to 4 > 4	0 0.33 0.66 1	Household members who were dropped out of school or could not attend school after the flood are more vulnerable	[43,67]
5	Households with a recent death in the family	Yes No	1 0	Households with recent deaths are mentally and psychologically disadvantaged and hence increase the vulnerability in case of a flood event	[76]
Social					
6	Family size	< 5 5 to 9 > = 10	0.33 0.66 1	Larger the family size, greater the number of people who are vulnerable to flood events	[34,56,59,104]
7	Type of family	Nucleus Joint	1 0.5	The joint family will be less vulnerable due to social capital	[41,84]
8	Female to male ratio (Physical Dependency Ratio)	< 1 1 to 2 2 to 3 > 3	0.25 0.5 0.75 1	Females are more vulnerable than males due to restricted mobility and limited physical strength	[34,82,104]
Financial					
9	Family income (in Pakistani Rupees - PKR)	< =5000 5001–10,000 10,001–15,000 15,001–20,000 > 20,000	1 0.8 0.6 0.4 0.2	Low income household are more vulnerable and have limited capacity to recover from flood	[44,59,92,99]
10	Primary occupation	Government Commerce and trade Agriculture Daily wage Unemployed	0.2 0.4 0.6 0.8 1	Government employment is more secure in case of floods than other occupations, like those associated with agriculture	[34,84]
11	House ownership	Owned Rented	0.5 1	House tenant cannot repair, maintain their building against floods	[34,59,99]
12	Household taking loans from others	Yes No	1 0	Household borrowing money from others are economically disadvantaged and hence more vulnerable	[43,77,78]
13	Loss of harvested/stored crops/grains for sale and family usage	Complete Partial No loss	1 0.5 0	Loss of harvested/stored crop/grains affects the income and food security of an household and hence increases vulnerability	[28,54,75,91]
14	Loss of livestock	Yes No	1 0	Loss of livestock affects food and income security	[5,28,54,75]
Physical					
15	Location of the house	Next to River Next to Dike but not Protected Protected by Dike	1 0.66 0.33	Houses next to the river are more exposed and vulnerable than those near a dike or protected by it	[34,48,78,86]
16	Type of house (construction material)	Pacca Semi-Pacca Katcha	0.33 0.66 1	Pacca houses are less vulnerable to flood compared to katcha (mud) houses	[16,39,42,92]
17	Loss/damage to the house	Complete Partial No Damage	1 0.5 0	The extent of loss/damage of house shows that area is prone to flood hazards	[28,54,75,76,105]
18	Damage and loss of village physical infrastructure	Complete Partial No Damage	1 0.5 0	Damage to village roads and drainage system limits the mobility of people and emergency vehicles, and restricts recession of flood water	[28,54,105]
19	Health facility damaged by flood	Complete Partial No Damage	1 0.5 0	Damage to health facilities hinders the delivery of health services in the neighborhood and hence increases the vulnerability	[54,91,105]
20	Schools damaged by flood	Complete Partial No Damage	1 0.5 0	Damage to schools affects the education and escalates vulnerability	[54,91,105]
21	Access to safe drinking water during and after the flood	Yes No	0 1	Households with no access to drinking water are more vulnerable	[5,24,43,77,106]
22	Access to sanitation facilities during and after the flood	Yes No	0 1	Households with no access to sanitation facilities are more vulnerable	[5,48]
Natural					

(*continued on next page*)

Table 1 (*continued*)

Sr. #	Indicators	Classes	Weights	Explanation	References
23	Farmland degradation	Yes No	1 0	Farmland degradation affects crop cultivation and productivity	[12,42,54]
24	Degradation of water quality	Yes No	1 0	Degradation of water quality affects human and crop health	[54,55,78]
25	Loss of standing crops	Complete Partial No loss	1 0.5 0	The extent of loss of standing crops deprived the farmers of their primary/secondary income sources	[42,54,105]

Table 2
Capacity indicators, associated weights, their explanation and references.

Sr. #	Indicators	Classes	Weights	Explanation	References
Human					
1	Education attainment of household head	College/ University High School Middle School Primary No education	1 0.75 0.5 0.25 0	Higher education of household head will help in better understanding of protocols and communication during floods	[5,42,43,77,78]
2	Households having multiple skills	Yes No	1 0	More skills like welding, plumbing will help in procuring extra livelihood sources	[74]
3	Households having knowledge of evacuation routes	Yes No	1 0	Timely rescue and evacuation	[7,12,103]
Social					
4	Households having a person which member of any association/union	Yes No	1 0	Membership in any association/union can help a household with information, raise their issues at various platforms and hence can add to capacity in case of a flood event	[5,15,74,77]
5	Households having good relations/trust within the community.	Yes No	1 0	Good relationships with neighbors and community members can increase capacity in the form of information dissemination and help in evacuation	[25,41,74,89]
6	Households having access to public representatives and local government officials	Yes No	1 0	Access to public representatives and government officials allows people to express their problems	[8,77]
7	Households having relatives outside the flood-prone area	Yes No	1 0	Households can move to relatives in case of a flood event and return when flood recede	[25,84,86]
8	Time taken to receive the early warning	More than 1 week before 3 days before A few hours before Not received	1 0.66 0.33 0	Timely warning of flood hazard allows people to harvest their crops and move their belongings to safe places to minimize losses	[42,69]
9	Availability of doctors in the community	Yes No	1 0	Fully equipped health center (with doctors, nurses, and health equipment)	[82]
Financial					
10	Households having multiple sources of income	Yes No	1 0	More than one source of income increases the capacity: if one source is affected by the flood, people can use another source to survive	[43,47,77]
11	Households having multiple earning members	> 3 3 2 1 0	1 0.75 0.5 0.25 0	Higher the number of earning members, higher will be the capacity	[74,86]
12	Get a cash grant from the government	Yes No	1 0	Household receiving cash grants against their losses are more able to recover from losses	[6,15,76,81]
13	Land Owned	Landless < 1 Acre 1 to 3 Acre 4 to 6 Acre 7 to 9 Acre 10 and more	0 0.2 0.4 0.6 0.8 1	Household which owns more land has higher capacity	[2–4]
Physical					
14	Following building regulations in reconstruction	Yes No	1 0	It is reconstruction, so if they are following it their capacity is increasing	[24,69]
15	Availability of safe access to main roads during and after the flood	Yes No	1 0	Safe access to main roads provides ease in emergency and evacuation and lowers vulnerability	[60]
16	Adoption of resilient techniques for house reconstruction	Yes No	1 0	Resilient techniques increases capacity against future floods	[49,69,102]
17	Govt./NGO providing resources for house reconstruction	Yes No	1 0	Households getting building material from NGOs for house reconstruction have more capacity to reconstruct	[9,54]
Natural					
18	Changing cropping pattern	Yes No	1 0	Changing cropping pattern reduces the chance of future losses of crops	[3,4,8,76]
19	Use of bio-fertilizers for improvement of soil	Yes No	1 0	Use of bio-fertilizers reduces expenses of chemical fertilizers to improve degraded soil and hence adds to the capacity	[8,54]

Table 3
Socio-economic profile of households in study areas.

Indicators	Categories	Jhang	Muzaffargarh	Overall
		% (N = 60)	% (N = 60)	% (N = 120)
Literacy	Illiterate	56.7	71.7	64.2
	Literate	43.3	28.3	35.8
	Mean	0.43	0.28	0.36
	Std Dev	0.500	0.454	0.482
Family size	< 5	5.0	–	2.5
	5 to 9	55.0	41.7	48.3
	> =10	40.0	58.3	49.2
	Mean	2.35	2.58	2.47
	Std Dev	0.577	0.497	0.549
Occupation	Government	11.7	5.7	9.2
	Commerce and trade	5.0	3.3	4.2
	Agriculture	28.3	33.3	30.8
	Daily wage	50.0	56.7	53.3
	Unemployed	5	–	2.5
	Mean	3.07	3.40	3.23
	Std Dev	1.219	0.848	1.059
Monthly family income (in PKR)[3]	< 5000	21.7	16.7	19.2
	5001–10000	25.0	31.7	28.3
	10,001–15000	35.0	28.3	31.7
	15,001–20000	10.0	18.3	14.2
	> 20,000	8.3	5.0	6.7
	Mean	2.58	2.63	2.61
	Std Dev	1.183	1.119	1.147

[3] 1USD = 123PKR in September 2018.

Table 4
Vulnerability and capacity index values for sub-district Jhang and Muzaffargarh.

Dimension	Vulnerability Index Values			Capacity Index Values		
	Jhang	Muzaffargarh	Overall	Jhang	Muzaffargarh	Overall
Human	0.250	0.278	0.264	0.370	0.293	0.331
Social	0.678	0.663	0.670	0.276	0.308	0.292
Financial	0.454	0.459	0.456	0.340	0.401	0.370
Physical	0.692	0.805	0.748	0.195	0.175	0.185
Natural	0.553	0.492	0.522	0.308	0.408	0.358
Overall	**0.528**	**0.562**	**0.545**	**0.291**	**0.308**	**0.299**

compared to Jhang is due to the presence of more vulnerable groups (such as elderly and children under the age of 15). Most of the people who suffered injuries during the flood events were children and the elderly. With regards to social assets, Muzaffargarh is slightly less vulnerable than district Jhang despite having larger family size. Nevertheless, an intense joint-family structure in Muzaffargarh reduces its vulnerability. It is noticed that larger household sizes have a higher number of children under the age of 15 – and therefore, these are the households which face more children dropping out of school. Additionally, larger households experienced more health problems than households with smaller family size. Fever, diarrhea and skin problems were heavily reported during and after flood events causing an additional financial burden on poor households for medical treatment.

Financial vulnerability for both Jhang and Muzaffargarh is almost the same. Both sub-districts are characterized by low income. Dependency on wage employment or agriculture for income generation and suffering of losses of stored food and harvested crops has increased their vulnerabilities. A majority of the population in rural areas are farmers or daily wagers on farms. The damage to crops and farms caused by a flood event resulted in deprivation of both farmers and daily wagers of their primary income sources. In addition, floods brought already disadvantaged households to poverty traps and escalated their financial vulnerability.

Physical vulnerability was high in both sub-districts, but it was higher for Muzaffargarh when compared to Jhang (see Table 4 and Fig. 2a). Location, type, and extent of damage to the house as well as loss of village physical infrastructure are core factors in increasing physical vulnerability. Most of the households live next to the river unprotected by structural measure. In Muzaffargarh, the extent of damage to the houses, village roads, electricity, and drainage system was very high. Damage to such infrastructure facilities hindered rescue and relief operations and created communication problems. People mainly use mud or adobe bricks to construct their houses which is highly susceptible to flood hazard and therefore Muzaffargarh experienced more damages compared to Jhang. Moreover, lack of access to drinking water and sanitation facilities during and after the flood was seen to exacerbate the vulnerability situation in the sub-district.

The vulnerability of natural assets was slightly worse in Jhang than Muzaffargarh as demonstrated in Fig. 2a. In comparison with Muzaffargarh, it was found that in Jhang the farmland degradation and loss of standing crops were much lower whereas the degradation of groundwater quality was much higher. As a result, overall vulnerability to natural assets was found to be higher in Jhang than in Muzaffargarh. It was also observed that open drains carrying sewage from the city passed from these flood-prone rural settlements, and, with flood occurrences, manure mixed with flood water deteriorated the water quality.

4.3. Capacity assessment

Analysis of capacities of target communities indicated striking

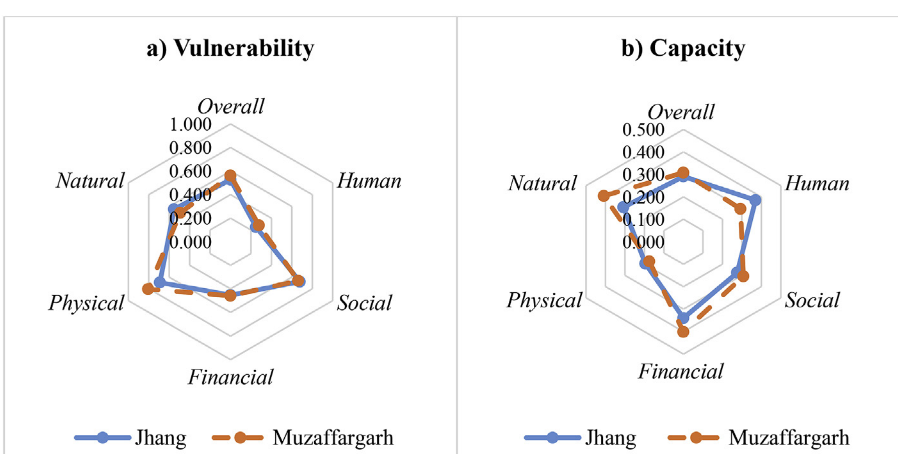

Fig. 2. a) Vulnerability and b) Capacity assessment in district Jhang and Muzaffargarh.

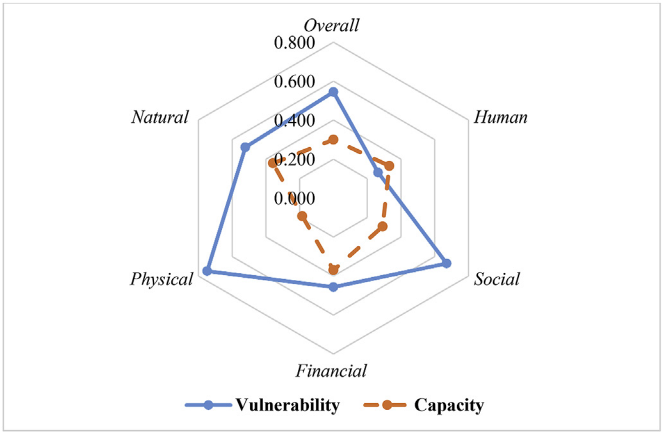

Fig. 3. Overall vulnerability and capacity associated with livelihood assets.

differences between the two study areas. Muzaffargarh was found to be slightly more capable of handling floods than sub-district Jhang, particularly in terms of social, financial and natural capital (Table 4 and Fig. 2b). This indicated that Jhang is at higher risk than Muzaffargarh.

Muzaffargarh lags in human capacities particularly when it comes to educational attainment, skills, and knowledge of evacuation routes (see Fig. 2b). In Jhang, literacy rate is higher than in Muzaffargarh and households possess more skills which can be used as an additional source of livelihood. Capacities in terms of social assets were found to be better in Muzaffargarh due to more effective early warning systems and strong social connection within the neighborhood. However, in Jhang, ineffective warning system and lack of access to the public representative (as well as limited participation in unions/associations) reduced the social capacities of the flood victims. Strong social networks within the community help people in evacuation and disseminating flood-related information as was noticed in the case of sub-district Muzaffargarh. Moreover, social connections provided financial and moral support to flood victims.

In the context of financial capacity, sub-district Muzaffargarh overtakes sub-district Jhang (see Table 4 and Fig. 2b). Households possess more financial assets than in sub-district Jhang, particularly when it comes to cash grant from government, ownership of land, and multiple earning members in the household. Cash grant was distributed based on damaged cropped area and damaged houses [55]. Since Muzaffargarh has experienced more losses to standing crops and houses, more households have received cash grants. The sub-district was also massively affected in the 2010 flood and was focused more by government and NGOs for relief and recovery efforts. Households reported that with multiple earning members, even if the flood affects the livelihood of one member, other members of the family could take care of the household needs, especially in the recovery phase. The analysis further revealed that after the flood, people started sending their children to work to recover from losses which hampered their education and affected their health.

Capacities associated with physical assets are limited in both sub-districts. Households in both sub-districts lacked the physical capacities such as the use of resilient technologies in reconstruction, following building regulation and safe access to main roads. It was noted that the majority of people were not aware of local building regulations and resilient technologies. Moreover, they did not have sufficient capacity to incorporate the regulation or resilient measures. Those who had knowledge of regulations claimed that building regulations did not represent the rural character and needed to be revised. Furthermore, results suggest that physical infrastructure (like roads) are in poor shape and have not been reconstructed since the massive flood event of 2010 which hindered the evacuation process in following flood events.

Muzaffargarh demonstrated better capacities to cope and adapt to the natural dimension as shown in Fig. 2b. Flood victims were seen to have changed their cropping patterns keeping in view the continuous flood events. They changed the timing for cultivation and harvest. Some households reported that they were cultivating vegetables instead of their usual crops since vegetables have less maturity period and they can be harvested quickly. Such practices are limited in sub-district Jhang. Overall, flood victims in Muzaffargarh are slightly more capable of dealing with flood hazards, particularly due to having more financial and natural capacities. However, compared to vulnerability, capacities were found to be much less in both sub-districts. Moreover, even though Muzaffargarh is more vulnerable than Jhang, it shows a higher capacity to deal with floods.

4.4. *The relationship between vulnerability and capacity*

4.4.1. *Overall vulnerability and capacity*

Analysis suggests that vulnerability overweighs the capacity of households in sub-districts highly affected by floods. It is important to note that flood victims have a higher capacity in terms of human and financial capital. Social, physical and natural assets are substantially affected by flood and households possess least capacities in these dimensions (see Table 4 and Fig. 3). Socio-economic factors, especially family size, access to institutions and income levels and associated flood losses are central to increasing vulnerability. Lack of attention of the local government on the development and improvement of physical and social infrastructure further exacerbates the vulnerability of communities already in possession of limited capacities. Moreover, there are capacity measures like multiple earning members (sending children to work) which increases vulnerability in the long run.

4.4.2. *Vulnerability vis-à-vis capacity*

Pearson's correlation test was employed to identify the relationship between vulnerability and capacity (see Table 5). The results revealed that vulnerability and capacity are negatively correlated with low to moderate values. In Jhang, a negative and significant correlation is observed between vulnerability and capacity ($r = -0.303$, p value = 0.05), whereas Muzaffargarh showed a negative correlation but was not significant since it has more vulnerability and at the same time more capacity than Jhang. Overall, a negative and significant relationship is seen in the flood-prone rural communities ($r = -0.216$, p value = 0.05). Our study confirms linkages between vulnerability and capacity. The results suggest an inter-dependency or association of these two concepts. This empirical evidence is backed up by a plethora of studies in the literature which emphasize that if capacity is low then vulnerability is high, and vice versa. However, this degree of association must be treated with caution as many unforeseen factors are at play. The study confirms outcomes with the research conducted in counties of USA (see Ref. [14]).

5. Conclusion

This study looks at the empirical relationship between vulnerability and capacity in Pakistan's flood-affected communities by utilizing an index-based approach. In existing literature, there is very little precedence for empirical approaches to determine the relationship

Table 5
Correlation between vulnerability and capacity of flood-affected communities.

Study areas	Pearson's Correlation
Jhang	−0.303*
Muzaffargarh	−0.112
Overall	**−0.216***

* Level of significance at 0.05.

between vulnerability and capacity. The adopted methodology, in addition to impact-based indicators, also used social, economic, environmental and physical indicators. The results show that there is a significant negative correlation between vulnerability and capacity. In both Jhang and Muzaffargarh – the two analyzed flood-affected districts in Pakistan – vulnerability patterns were found to be similar but capacities to cope with flood events demonstrated a dissimilar pattern. Inaccessibility to social institutions, low incomes, lack of basic physical infrastructure, and unawareness of potential risks (and therefore lack of appropriate preparations) was found to have aggravated vulnerability in both districts. The capacity measures, on the other hand, were found to be associated with human assets in Jhang and natural assets in Muzaffargarh, whereas financial assets were linked with capacities in both districts. Most of the flood victims exercised autonomous capacity measures, some of which were found to have negatives effects in the long-term resulting in increased vulnerability and, therefore, require second order adaptation (see Ref. [19]). It was also found that certain assets, in terms of vulnerability and capacity, one district overtook the other and vice versa, suggesting that vulnerability and capacity are "characterized by distinctive features of space, flood events, socio-economic and physical situations" [54]. In short, the results indicate that capacities to deal with flood events are significantly lower when compared with the vulnerabilities faced by both districts. It is recommended that the physical infrastructure of settlements requires improvement, i.e., proper drainage system, access roads, and evacuation routes. The local government should focus on providing immediate access to improved sanitation and safe drinking water. Additionally, the government should provide easy access to social support institutions (e.g. insurance programs should be designed particularly for flood victims to share their financial burdens) and provide opportunities for livelihood diversification. Institutions feedback and stakeholders' involvement in the future can help in identifying needs and priorities.

The primary focus of this study was to ascertain the relationship between vulnerability (exposure and susceptibility) and capacity. The analysis found out the negative correlation between these disaster risk components. The findings suggest that community capacities in terms of human, social, economic and physical domains must be developed to lower vulnerability. The results of the index-based approach specifically highlight the indicators which show possibilities for improvement and therefore have the potential to become the focal-points of future policies. This study's usefulness lies in its potential to guide disaster management experts, rural development authorities, and private sector institutions to identify central issues associated with vulnerability and capacity. However, this study utilized limited indicators and a comparatively small sample size and focused specifically on flood events and victims. In addition, advanced statistical methods and expert assessments can be used to allocate weights for each indicator to further increase the accuracy of the methodology used in this study. Moreover, the validation of results with the real event was not possible due to the absence of database and differing viewpoints of local officials and donors. A larger sample size, a broader set of indicators, and analysis of other climate-related disaster events can establish more concrete findings in the future.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ijdrr.2019.101109.

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